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Impact Of Heavy Metals On The Environment And Human Health

Mrs.Sunita Nagpal
Associate Professor
Department Of Chemistry
Dr.Bhim Rao Ambedkar Government College
Sriganganagar

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Abstract

The toxicity, lengthy half-life in the atmosphere, and capacity to bioaccumulate in the human body make heavy metals well-known environmental contaminants. There are several ways that humans might be exposed to heavy metals, such as through the food chain, contaminated water or soil, or inhaling dust or air particles. Their bioaccumulation could result in a variety of harmful effects on various organ systems and bodily tissues. Heavy metal toxicity is determined by the metal's characteristics, dosage, exposure route, length of exposure (acute or chronic), and degree of bioaccumulation. Research has indicated that urban soils frequently contain greater levels of specific heavy metals, such as lead (Pb), copper (Cu), and zinc (Zn), which are frequently linked to industrial processes, building, and vehicle emissions. In contrast to agricultural fields, urban green spaces had higher mean concentrations of Pb, Cu, and Zn, according to a study on urban green spaces and agricultural land uses. There were notable differences in the concentrations of certain heavy metals in the soil, water, and specific crop samples. Significant progress is being made in the analysis and extraction of heavy metals from complex matrices via nanotechnology, a developing discipline. Numerous nanomaterials, such as graphene and its derivatives, magnetic nanoparticles, metal oxide nanoparticles, and carbon nanotubes, have been used to remove heavy metals. There are numerous advantages to using nanotechnology for heavy metal analysis and removal from food and water sources as opposed to more conventional techniques.

Keywords: Heavy metals, Environmental health, Toxicity, Nanotechnological Approaches, Nanomedicine.

Introduction

Heavy metals make up a significant chunk of the periodic table due to their large atomic weight and density. The majority of them are found in the biosphere, which

includes rocks, soils, and water. Other manmade resources, primarily commercial and industrial, also release them into the environment[1]. For many years, the harmful properties of heavy metals have been understood. Recent experimental studies, however, have demonstrated that several, such as zinc, copper, and nickel, are abundant in nature and essential to human health. [1]

Globally distributed, manganese comprises around 0.1 percent of the earth's crust. Heavy metals, however, have a lot of negative effects on the environment. For instance, when mercury is converted to methylmercury in the presence of water, it produces very poisonous sediments[1-2]. chromium is used extensively in industry and has the potential to cause cancer. Nonetheless, several heavy metals play a role in regulating specific physiological processes in the body. Via food, air, and water, naturally occurring essential heavy metals enter the body and control a wide range of biological processes[2].

The majority of hazardous heavy metals, such as lead, thallium, cadmium, and antimony, are frequently found in industrial processes and significantly contaminate the environment. Although it is less common in nature, thallium has a more severe effect than other heavy metals and can induce baldness in people[3]. The risks associated with heavy metals typically outweigh the advantages; for instance, high exposure to chromium and antimony promotes carcinogenicity[4], and lead poisoning results in intellectual impairments in children. Minamata illness is caused by mercury toxicity, whereas itai-itai disease is caused by cadmium poisoning. In addition, heavy metals have the potential to be harmful to the human body's organs, including the kidneys, brain, liver, skin, and heart. People must relocate away from industrial locations with high levels of heavy metal emissions in order to prevent hazardous impacts[4-5].

The persistent, poisonous, and bioaccumulative nature of heavy metals (HMs) makes soil contamination a major global environmental problem [1, 2]. The buildup of heavy metals (HMs) not only reduces the production and quality of agricultural products, but it also degrades soil quality and has a direct impact on the physical and chemical characteristics of the soil [3, 4]. HMs, or potentially hazardous substances, have accumulated in soil as a result of agricultural practices, urbanisation, and industrial growth during the past few decades [5]. Numerous geo-environmental factors, including

the composition of the parent rocks and the types of human activities, including the use of agricultural pesticides, influence the ultimate location and effects of such pollutants [4]. The likelihood that plants will absorb these metals can be increased by higher soil concentrations of HMs [1]. Therefore, in order to guarantee the safe use of inorganic fertilisers, organic waste, and pesticides during crop production, comprehensive risk evaluations of heavy metal buildup in farmlands are necessary [2]. Some metals, such as As, Cr, Cd, and Pb, can be poisonous even at low concentrations and pose serious risks to plant, animal, and human health through the food chain, whereas others, such as Mn, Fe, Cu, and Zn, are necessary in trace amounts for biological activities [3].

The more common metals in the Earth's crust are iron and manganese, which are commonly found in Fe/Mn hydroxides and oxides. When predicting whether specific heavy metals would dissolve or precipitate in soil, these hydroxides and oxides are essential [5]. On the other hand, most metals are usually eliminated through animal excrement, although some, like Zn and Cu, are commonly added to animal feeds for their growth-promoting and antibacterial properties [6]. One of the biggest problems facing the globe today is the poisoning of plants and water by heavy metals, which needs to be addressed. Excessive levels of heavy metals pose a serious risk to plant and animal life. The overuse of pesticides, fertilisers, irrigation, atmospheric deposition, and industrial effluents are some of the causes of heavy metal contamination in many ecosystems. Careful soil management is based on an accurate understanding of heavy metal concentrations, their forms, and how they depend on the physicochemical characteristics of the soil [3]. Heavy metal motilities may be caused by inadequate management of soil and water resources, which could lead to their entry into the food chain. The majority of heavy metals build up on soil surfaces and in the topmost sedimentary layers of water basins. They alter their properties by combining with the materials found in these upper layers. The mobile form of organic materials and heavy metal concentrations in sediments is conditioned by the pH of the soil, which acts as a buffer and stores these materials for a long period of time [2–6]. In the past, a study was conducted in Bikaner to evaluate the levels of heavy metal contamination in vegetables that were irrigated with waste water. The study's findings indicated higher

levels of Cu, Mn, Zn, and Fe. There was some information about the area's exposure to heavy metals. In order to learn more about the problems associated with heavy metals and how they contaminate the water, soil, and a few chosen crops in the Sri Ganganagar district, the current study was conducted. Because of their potential advantages in eliminating the negative effects of heavy metals, nanotechnological methods are also gaining interest. Using ideas from physics, chemistry, engineering, and biology to create materials or devices at the nanoscale is known as nanotechnology. As nanotechnology has grown, heavy metal detection and removal nanomaterials have been meticulously created and produced, offering numerous advantages[4].

Heavy Metals In The Environment

Although heavy metals are necessary for survival and are found naturally in the environment, they can become dangerous when they build up in living things. Mercury, cadmium, arsenic, chromium, nickel, copper, and lead are among the most common heavy metals that pollute the environment[[5].

Animals and humans can be exposed to cadmium in many ways, and it can be released into the atmosphere as a result of natural or man-made activities. Surface runoff into sediments, industrial waste, and absorption all contribute to cadmium poisoning of the aquatic environment. Cadmium poisoning occurs when a person consumes food, breathes in air, or drinks water contaminated with the metal. cadmium has no qualities that are beneficial for plant growth or metabolic activities[4-6].

One of the most dangerous heavy metals that can be present in the biosphere is mercury. It has also expanded far and is becoming more prevalent in the atmosphere as a result of human activity. When mercury comes into touch with aquatic sediments, it transforms into the extremely hazardous methylmercury[6]. Through the food chain, methylmercury enters the human body through fish, seafood, and wildlife that have been contaminated by consuming harmful microbes. After being absorbed into the human body, it enters the bloodstream and results in a number of neurological issues[6].

Lead is a metal that is present in nature in comparatively small levels and is not biodegradable. Because of human activities like mining, manufacturing, and burning fossil fuels, atmospheric lead levels are steadily rising. When exposed to higher than ideal levels, lead is hazardous to the human body. Children are more susceptible to

lead poisoning, and the severity of the illness worsens when they come into touch with dust that contains environmental lead[7].

The most common of the harmful heavy metals, manganese, can be found in nature in a variety of oxidation states. Manganese oxides are released into the atmosphere when methylcyclopentadienyl manganese tricarbonyl (MMT), a petrol additive, burns. Despite being necessary for many physiological processes, manganese can be extremely hazardous if consumed in excess. [7]

The metal chromium is poisonous and carcinogenic. It can be found in two stable oxidation states in the environment: chromium (III) and chromium (IV) (VI). A less dangerous version of chromium (VI) is chromium (III). During industrial activities, they have the ability to interconvert to one another. However, because chromium (III) is less poisonous than chromium (VI), its conversion is less detrimental to the environment. Numerous enterprises that employ chromium endanger local climates. The emissions from the ferrochrome industry are the largest when compared to environmental natural chromium emissions (Fig. 1) [8]

Figure 1: Diagrammatic explanation about heavy metals in the environment[4]

Nanogramme levels of the toxic metal antimony can be detected in the atmosphere. Emissions into the atmosphere are caused by both man-made and natural processes, such as weathering and volcanic activity [8]. Inhalation of antimony can cause poisoning in industrial workers (Fig. 1). Pancreatitis, cardiotoxicity, and respiratory issues (pleural adhesions, chronic emphysema, chronic bronchitis, respiratory irritation, and dormant tuberculosis) are among the physiological deficiencies brought on by antimony poisoning. Additionally, it damages reproduction and causes cancer. Thallium is

dangerous to living things and can be found in the environment in a variety of forms. Of all the heavy metals, thorium is the most hazardous. monovalent thallium ions form in natural water and are released into the atmosphere by an aqueous pathway (Fig. 1). Furthermore, one of the main causes of the rise in thallium levels in the atmosphere is industrial pollutants. Humans are severely harmed by thallium exposure[9].

Soil Types And Irrigation Practices

The district's northern region is distinguished by cierozem, or dry soil, which ranges in colour from pale to yellowish brown. Between 75 and 100 cm of depth was where the cancar layer (estimated concrete) was discovered. The soil has a gentle drainage and is deep. Natural fertility and moisture retention are often low, and permeability is moderately slow to fairly sluggish [2]. The most common types of soil that contain this soil category are clay sand and sandy clay. The area also has sand streaks. The district's southern section is distinguished by desert floors, which are often devoid of lime concrete and have a very light brown to yellowish colour. The floor has a high permeability, a low moisture container capacity, and is normally well-drained. Although fountains and pipe holes pass through multiple locations, the district's primary watering agents are channels [7].

Heavy Metal Analysis

- **Metal Selection:** Lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn) are among the metals that the study is most likely to concentrate on.
- **Analytical Methods:** The amounts of these metals would be ascertained using methods such as inductively coupled plasma mass spectrometry (ICP-MS) or atomic absorption spectroscopy (AAS)[7].

Exposure To Heavy Metals And Environmental Pollution

By binding to sulfhydryl groups and producing reactive oxygen species (ROS), heavy metals cause toxicity to biological systems (Figure 2). This results in oxidative stress, glutathione depletion, and the inactivation of essential macromolecules. Numerous mechanisms, such as interaction or inhibition of certain metabolic pathways, occur after exposure to hazardous metals and entry into the body [4-6]. Numerous detrimental consequences on both humans and animals are therefore noted.

These include diseases of the immune system, cancer, congenital conditions, metabolic disorders, changed hormones, and specific organ dysfunctions[4]. As a result, a lot of international

organisations establish guidelines for the levels of metals in food, drinking water, and the environment. Heavy metal levels in food and water are examined in risk assessment studies. About one-fifth of the 193 Ayurvedic and well-known Indian herbal remedies that [4] examined included mercury, lead, and arsenic. Nearly 21% were found to have measurable levels of As, Pb, and Hg. Notably, every product that included metal went beyond and beyond one or more recommended daily metal consumption criteria. This could lead to ingestions of Pb and/or Hg that are 100–10,000 times higher than permissible levels. In addition, the amount of metals that can enter the body each day is controlled. Regulatory bodies should set daily dosage limits for heavy metals in dietary supplements. Additionally, producers must evaluate their products for standard compliance. Even the most pristine areas are now affected by environmental contamination. Heavy metals Pb, Cd, Cr, As, and Hg were found even in remote areas like Mount Everest. The levels of As and Cd in every Everest snow sample were greater than those recommended by the USEPA for drinking water. In addition, every soil sample had substantial levels of As contamination. Samples were taken from Sri Ganganagar's agricultural locations throughout the post-monsoon seasons in order to analyse the levels of heavy metals in the water, soil, and crops. Water Samples were collected in polycarbonate bottles that were rinsed multiple times with distilled water after being properly cleaned with nitric acid. Following the wet season, samples of soil from the superficial mineral layer (5–20 cm) and crop leaves were gathered from an area with a lot of agricultural cover [7]. Samples of soil were air-dried at 20° C and milled in a mortar to fit through a 2 mm sieve before analysis. The chosen crops' leaves were properly cleaned in deionized water to get rid of any particles, then dried at 70° and ground into a powder. The firm Borosil glass tube was filled with 0.5 gramme of soil and crop samples that had been weighed. Each sample received a 4:1 addition of concentrated nitric acid and perchloric acid. The samples were submerged in a water bath for five to six hours, or until they were fully digested and transparent. The fat was then neutralized and dissolved by adding three to four drops of 30% H_2O_2. Each sample was cooled, then diluted with 10 milliliters of deionized water, placed in a sterile Borosil glass vial, and allowed to cool at room temperature before analysis [8].

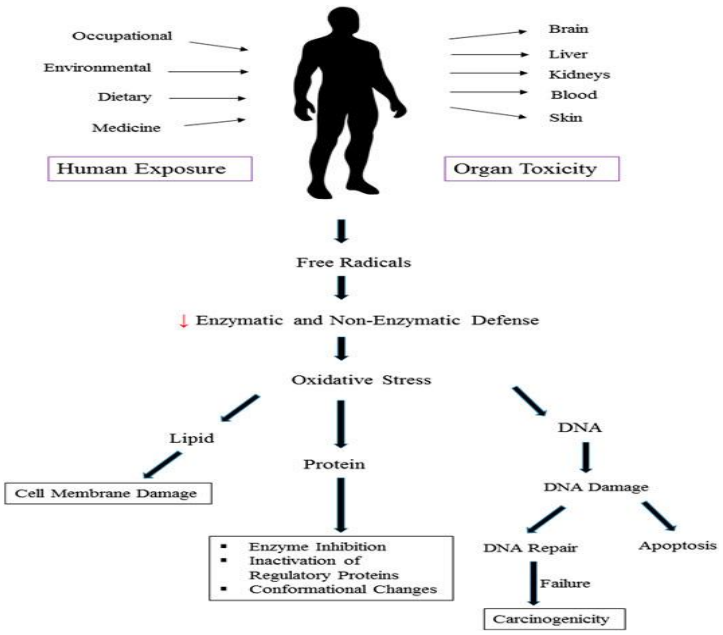

Figure 2: Oxidative stress and organ toxicity following exposure to heavy metals[4].

Material And Methods

Results And Discussion

Evaluation of Heavy Metals in Soil and Water: Eighty samples were examined for the presence of nine major heavy metals in Sri Ganganagar district's soil and water. Agrochemical application intensity, population distribution, and substantial agricultural activities were taken into consideration when choosing the various areas. Zn: 0.138 ppb, Pb: 0.125 ppb, Cu: 0.030 ppb, Cd: 0.006 ppb, Fe: 1.583 ppb, Ni: 0.068 ppb, Cr: 0.125 ppb, Mn: 0.076 ppb, and Co: 0.033 ppb were the average concentrations of the various heavy metals in water samples. The sequence of heavy metal contamination in water samples was Fe > Zn > Cr > Pb > Mn > Ni > Cu > Co > Cd. The average amounts of various heavy metals were also found to be Zn: 0.125 ppb, Pb: 0.125 ppb, Cu: 0.025 ppb, Cd: 0.003 ppb, Fe: 12.70 ppb, Ni: 0.050 ppb, Cr: 0.163 ppb, Mn: 0.376 ppb, and Co: 0.020 ppb, according to the study's examination of soil samples (Table 1)[8]. The order of heavy metal contamination in soil samples was Fe>Mn>Cr>Zn>Pb>Ni>Cu>Co>Cd. The average concentration of heavy metals in water was significantly higher than in soil, which is an interesting finding. Their percolation in ground water could be the cause. Ground water contamination may be caused by

heavy metals that are naturally present as water-soluble salts and released from various agrochemicals used on crops [9].

Table 1: Levels Of Several Heavy Metals In Water and Soil [9]

S.No.	Heavy Metal	Soil (ppb)			Water (ppb)		
		Min.	Max.	Ave.	Min.	Max.	Ave.
1	Zn	0.1	0.3	0.2	0.2	0.3	0.25
2	Pb	0.2	0.4	0.3	0.1	0.3	0.2
3	Cu	0.11	0.14	0.125	0.12	0.14	0.13
4	Cd	0.011	0.023	0.017	0.024	0.028	0.026
5	Fe	12.22	17.92	15.07	0.13	5.12	2.625
6	Ni	0.22	0.38	0.3	0.24	0.29	0.265
7	Cr	0.3	0.4	0.35	0.2	0.4	0.3
8	Mn	0.36	0.45	0.405	0.13	0.5	0.315
9	Co	0.22	0.34	0.28	0.21	0.35	0.28

The current study's findings may be related to those of a previous investigation that was conducted in parts of Morocco's Kettara abandoned mine and that described how certain metals moved via soil and water [9]. Certain Crops Contain Heavy Metals: Four important crops Cyamopsis tetragonoloba (Gawar), Vigna radiata (Moong), Pennisetum glaucum (Bajara), and Gossypium arboretum (Narma) were chosen for the current study in order to evaluate the effects of heavy metals on crops growing in areas affected by heavy metals. Selected crops' concentrations of Zn, Pb, Cu, Cd, Fe, Ni, Cr, Mn, and Co were examined. Rope samples were gathered from seven distinct locations. To ascertain the heavy metal concentration of the various crop sections (roots, leaves, and leaves), all of the samples were examined. Numerous researchers in various regions of India have detected heavy metal toxicity (Pb, Cd, Cr, Cu, Mn, etc.) in animals as a result of polluted fodder [10]. Gawar had the highest average concentration of Cd (0.005 ppb), whereas Bajara had the lowest average value (0.001 ppb). Vegetables cultivated on waste disposal sites in Kumasi, Ghana, were the subject of a similar study that revealed high levels of cadmium contamination (0.68%–1.78% mg/kg)[10]. Because of its propensity to cause cancer and its link to kidney and bone damage, cadmium toxicity in wastewater-irrigated crops is becoming a bigger health problem. The most prevalent metals in crops are generally copper and zinc, which are also vital micronutrients for

plants [8]. Gawar had the highest recorded concentration of zinc (0.300 ppb), whereas Narma had the lowest average concentration (0.150 ppb).Likewise, the higher level of Cu was mirrored in the average concentrations of Moong (0.042 ppb) and Gawar (0.050 ppb). Ni concentrations were found to be on average 0.059 ppb in Bajara and 0.058 ppb in Gawar. Plant height, shoot and root biomass, leaf soluble sugars and starch, and the Ni contents of the shoots and roots were the plant metrics utilised to examine how heavy metals affected their growth. The growth, morphology, photosynthesis, mineral nutrition, and enzyme activity of plants were all impacted by nickel's general reduction of leaf soluble sugars [9].Bajara has the highest average concentration of iron (6.945 ppb). Due to its several biologically significant roles in photosynthesis and biosynthesis, iron is one of the elements that all plants require. Gawar had the highest average Mn concentration (0.261 ppb), whereas Bajara had the lowest (0.196 ppb). The current investigation's results are consistent with a study that found that an excess of manganese (Mn) in leaves lowers the photosynthetic rate [10].

Conclusion

Most heavy metals exist in the environment and occur naturally. Some toxic heavy metals are emitted into the environment from anthropogenic sources. Exposure of the human body to heavy metals is either environmental, because the metal already exists in nature, or through foreign sources. This study's primary objective was to determine the levels of several heavy metals in the ground, water, and commonly growing plants in the districts of Sri Ganganagar. Assessing the levels of different heavy metals in the soil, water, and a few regularly produced crops in the Sri Ganganagar district was the primary goal of the current study. The concentration of heavy metals in water samples was found to be Fe> Mn> Cr> Zn> Pb> Ni> Cu> Co> Cd, but in soil samples, the concentration was found to be Fe> Mn> Cr> Zn> Pb> Ni> Cu> Co> Cd. People should not use chemical products where toxic heavy metals use extensively. Regardless, self-awareness may help everyone to reduce the attachment with heavy metals.Chronic low dosage exposure to numerous elements is a substantial threat to public health in many regions with metal pollution, particularly in places where metal pollution is ubiquitous. Understanding the mechanistic basis of heavy metal interactions is critical for the evaluation of health risks associated with chemical combinations and the management of such risks.

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